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MATHEMATICAL PHYSICS.—*Symmetry.*[1] HERMANN WEYL, Institute for Advanced Study, Princeton, N. J. (Communicated by IRVINE C. GARDNER.)

Symmetry, which is the subject of my talk tonight, plays an enormous rôle both in art and nature. I shall try to describe a little why and how this comes about, and by what concepts the mathematicians have approached this phenomenon. For, after all, symmetry is a mathematical concept.

In our everyday language and in the arts, the word symmetry is today used mostly for designating *bilateral symmetry*, the left- and

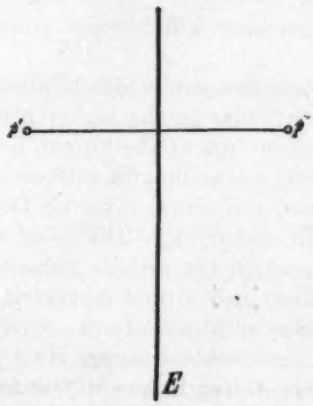

Fig. 1.—Reflection in E.

right-hand symmetry. Let us imagine a plane E in space and perform reflection in E; this is a mapping or transformation S of the whole space on itself $p \rightarrow p'$ by which every point p is carried over into a new point p' according to the construction indicated by Figure 1: dropping the perpendicular from p on E and prolonging it by its

[1] The eighth Joseph Henry Lecture of the Philosophical Society of Washington, delivered on March 12, 1938. The illustrating material used in the lecture could not be reproduced here. Received March 16, 1938.

own length. E acts here as a mirror. A figure is symmetric with the symmetry plane E if it goes over into itself by this transformation S.

I find it convenient to explain right at the beginning some simple general notions about mappings. Let S be a mapping carrying the arbitrary point p into $p'=pS$ and T another mapping carrying p' into $p''=p'T$; then the mapping which changes p directly into p'',

$$p''=(pS)T=p(ST)$$

shall be denoted by ST (first S, then T). The mapping which carries every point p into itself is called the *identity* J. For our reflection S in the plane E we have $SS=J$, because application of the operation S on p' changes p' back into p. The only transformations with which we shall be concerned are those that change every figure into a congruent one and thus are the result of a motion or of a motion combined with a reflection; we call them *proper* and *improper motions* respectively. The combination or "*product*" ST of any two motions S, T is again a motion, and so is the *inverse* S^{-1} of a motion S:

$$p'=pS,\ p=p'S^{-1}.$$

These general preliminaries will become clearer by the following applications.

You all know the eminent part which bilateral symmetry plays in organic nature, in particular in the higher branches of the animal kingdom and in the structure of the human body. As a reminder I show you two pictures: a bloodhound with deep and perfectly symmetric folds in his face, and this well-known Greek statue of a praying boy, from the 4th century B.C. The noble sculpture may at the same time bear witness to the artistic value of symmetry. It is a general experience that such formal geometric principles, like that of symmetry, hold sway most strictly in archaic periods, while they are apt to soften in more mature times. Here are a few pictures of Babylonian seal stones dating between 2900 and 2650 B.C., which I owe to the kindness of my Princeton colleague, Professor Herzfeld. Particularly impressive is the second, a god fighting a lion. The lower bull-shaped part of the god's body, rendered in profile, is doubled in order to secure the symmetry of the whole composition. Similar examples are the old imperial Russian and Austro-Hungarian double eagle.

For bilateral symmetry one needs neither the three-dimensional space nor even the two-dimensional plane: reflection is essentially a *one-dimensional* operation: a straight line can be reflected at any of its points O which serves as a symmetry center. The only other

motions of the one-dimensional line are *translations*, parallel displacements by an arbitrary distance a. A figure which is invariant under a translation a shows an "*infinite rapport*," i.e., repetition in a regular spatial rhythm of length a. *Rhythm*, whether in space or in time, is another esthetic principle of universal significance. Musical rhythm is its temporal form. A pattern invariant under the translation T is also invariant under its iterations

$$TT = T^2, \; TTT = T^3, \text{ etc.}$$

and under the inverse T^{-1} and its iterations. They shift the line by $1a$ $2a$, $3a$, . . . and by $-a$, $-2a$, ... All translations carrying over a given pattern on a straight line into itself are in this sense multiples

$$na \; (n = 0, \pm 1, \pm 2, \ldots)$$

of one basic translation a. This rhythmic symmetry may be combined with reflective. The centers of the reflections then follow each other with half the distance $\frac{1}{2}a$. Only these two types of symmetry, as illustrated by Figure 2, are possible for a one-dimensional pattern or "ornament."

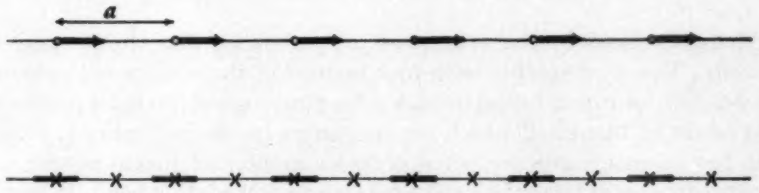

Fig. 2.—The two types of one-dimensional ornaments.

We pass from one to *two dimensions*. Here a new kind of symmetry crops up—symmetry with respect to *rotations* around a center O. The circle is in this regard the fully symmetric figure. A more limited rotary symmetry is represented by the regular polygons: All rotations around O carrying the figure into itself are the iterations of a certain aliquot part $360°/n$ of the full angle ($n = 1, 2, 3, \ldots$). We then call O an n-fold symmetry *pole*, or briefly an n-pole. The case where there is no rotary symmetry at all is included as $n = 1$. Flowers, nature's gentlest children, are charming examples of this kind of symmetry. Here is a picture of an iris with its triple pole, and here one of the quintuple flowers of hawthorn. The symmetry of 5 is most frequent among flowers. I emphasize this because, as we shall see later, it never occurs in inorganic nature, among the crystals. As a curiosity,

look at this inflorescence of a composite: the arrangement emulates exactly the structure of a regular pentagon-dodecahedron, although the photograph shows it but incompletely. But I shouldn't anticipate here the study of spatial symmetry!

Very frequently rotational symmetry is combined with reflective symmetry. Reflection in a plane takes place at lines, so-called symmetry *axes*, or briefly axes. If O is an n-pole, then the axes through O form angles of $360°/2n$ with each other. For instance, a 3-pole is combined with three axes forming angles of 60° with each other. Perhaps the simplest figure with rotational symmetry is the *tripod* ($n=3$). When one wants to prevent the attending reflective symmetry one puts little flags onto the arms and obtains the *triquetrum*, an old magic symbol; the Greeks, for instance, used it, with the

Fig. 3.—Tripod and triquetrum.

Medusa's head in the center, as a symbol for the three-cornered Sicily. The modification with four instead of three arms is the *swastika* of fylfot which I need not draw for you—one of the most primeval symbols of mankind, which we encounter in all civilizations; today it has become again for some people a symbol of magic power, for others a sign of terror like the snake-girdled Medusa's head. It seems that the origin of the magic power ascribed to these patterns lies in their startling incomplete symmetry—a center without axes. Here is the gracefully designed staircase of the pulpit of the Stephan's Dom in Vienna: a triquetrum alternates with a swastika-like wheel.

Magnificent examples of central symmetry are provided by the rose windows of the Gothic cathedrals. The richest I know is the rosette of St. Pierre in Troyes, France, which is based on the number 3 throughout. I show here one of the side portals of Notre Dame de Paris; and here a wonderful view of the Romanesque cathedral in Mainz, Germany, taken from the rear of the choir. Its severe and harmonious aspect is chiefly due to the wealth of simple symmetries: repetition in the round arcs of the friezes, octagonal central symmetry in the small rosette and the three towers, bilateral symmetry with vertical axes which rules the structure as a whole as well as almost every detail. In architecture, symmetry of 4 is prevalent. A

particularly pure example is Bramante's second plan of St. Peter's in Rome. Here is a view up into the tower over the crossing of Canterbury Cathedral. The hexagon occurs occasionally; I can recall S. Ivo alla Sapienza in Rome, and the Mariahilfskirche in Innsbruck, Austria. If I am not mistaken, the Zwinger in Dresden, Germany, is a regular 12-side. A pentagon I have seen only once, in a quite inconspicuous passage in San Michele di Murano in Venice. Leonardo da Vinci engaged in systematically determining the possible symmetries of a central building and how to attach chapels or niches without destroying the symmetry of the nucleus. Let us repeat the first part of his investigation in modern terminology.

A figure invariant under the transformations S and T is also invariant under the transformation ST. A motion carrying a figure F as a whole into itself may be called an *automorphism* of the figure. The automorphisms form what the mathematicians call a *group*. A set of transformations S is a group f if any two elements S, S' of f give rise to a compound element SS' again contained in the group. Our considerations lead up to this statement: *Symmetry is described by the group of automorphisms*, and this is the only truly adequate way.

Here we study at first plane symmetries around a center O, i.e., we limit ourselves to motions leaving O fixed. We call them rotations; the proper rotations are rotations in the ordinary sense, the improper ones are reflections in axes going through O. The proper rotations D leaving a given figure invariant form a group. Let ϕ be the angles of these rotations, $D = D_\phi$. If not *all* rotations occur as in the case of a circle, we shall have a rotation of smallest positive angle $\phi = \alpha$. Every ϕ must be a multiple of α:

$$\phi = m\alpha;\ m = 0,\ \pm 1,\ \pm 2, \ldots .$$

Indeed, if there were a ϕ lying between two consecutive multiples, $m\alpha < \phi < (m+1)\alpha$, then $(m+1)\alpha - \phi$ would be a positive symmetry angle smaller than α, contrary to the determination of α. In particular, since the figure is left unchanged by making a full turn, 360° must be a multiple of α. Hence α is an aliquot part $360°/n$ of 360°, and the whole group of proper rotations, as we mentioned before, consists of iterations of one basic rotation of angle $360°/n$, or of the operations which a dial with n equidistant marks permits. The group is called the *cyclic group* C_n. Its order, i.e., the number of its elements, is n. n is capable of the values $1, 2, \ldots$.

In a second step we propose to include the *reflections*. Let us draw

two axes 1 and 2 through O forming an angle $\alpha/2$, and let S_1, S_2 be the reflections in 1 and 2 respectively. The transformation $S_1S_2 = D_\phi$ is the proper rotation by the angle α, as shown by the simple construction in Figure 4. Hence S_2S_1 is the opposite rotation D^{-1} by $-\alpha$. In combining motions we must watch out for the order in which it is done; we see here that the result may depend on the order! From the equation $S_1S_2 = D_\alpha$ we obtain

$$S_1S_1S_2 = S_1D_\alpha \text{ or } S_2 = S_1D_\alpha.$$

Hence if the given figure F with the symmetry axis 1 permits the

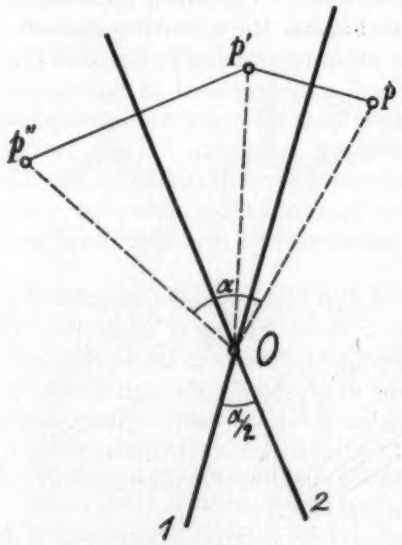

Fig. 4.—Rotation.

rotation D_α, then the line 2 forming the angle $\alpha/2$ with 1 will also be a symmetry axis. If the group C_n of proper rotations occurs together with reflections, we shall have exactly n different reflections whose consecutive axes form the angle $360°/2n$ with each other. The whole group consisting of these reflections and of the rotations by multiples of $360°/n$ is of order $2n$ and is called the *dihedral group* G_n. Thus, in agreement with Leonardo, these are the only possible central symmetries:

(*) $C_1, C_2, C_3, C_4, C_5, \ldots;$
$G_1, G_2, G_3, G_4, G_5, \ldots.$

C_1 means no symmetry at all, G_1 means bilateral symmetry and nothing else.

When we now turn to the study of *ornaments* covering the whole plane, we have to take into account all motions, not only those leaving fixed a pre-assigned center O. A proper motion in a plane is either a translation (parallel displacement, shift, as indicated by a vector) or a rotation with a fixed point (pole) A. An improper motion is either a reflection in an axis l or such a reflection combined with a parallel displacement along l by a certain distance a; in the latter case l may be called a gliding axis. Composition of translations is commutative; it amounts to forming the resultant of two vectors according to the well-known law of the parallelogram. If the group of automorphisms of a given ornament contains translations at all there are only two possibilities:

(1) All translations or vectors are multiples of one basic vector: simple infinite rapport or band ornament.

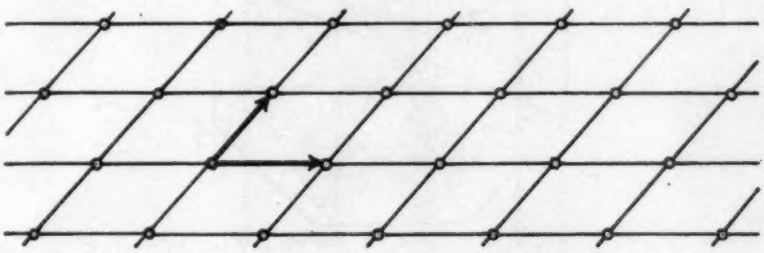

Fig. 5.—Parallelogrammatic lattice.

(2) They arise by composition from two basic vectors of different direction: double infinite rapport or surface ornament. We shall deal with this more interesting case only: Wallpapers, carpets, tiled floors and parquets, belong to this category. Once one's eyes are opened one will be surprised by the numerous symmetric patterns which surround us in our daily lives. The greatest masters of the geometric art of ornament were the Arabs, and I shall soon show you samples of their beautiful decorations. But first a little mathematics.

We choose an arbitrary point O in our plane and submit it to all the translations of our ornament. The result will be a parallelogrammatic lattice L (Fig. 5). Any motion S can be considered as a (proper or improper) rotation around O, followed by a translation. This decomposition is unique, and we call the first, the rotation part, the

reduced S. After reduction, the motions S which the given ornament permits, form a finite group f_o of rotations; hence one of the groups in the table (*). *Its operations carry the lattice over into itself*. This relationship between the rotation group f_o and the lattice L imposes certain restrictions on both of them.

(1) As to f_o, the values $n=2$, 3, 4 and 6 only are possible because a lattice cannot have any other symmetry. Hence the rotary parts of our automorphisms must form one out of the following 10 groups:

$$C_1,\ C_2,\ C_3,\ C_4,\ C_6,$$
$$G_1,\ G_2,\ G_3,\ G_4,\ G_6.$$

In particular $n=5$ is excluded. Indeed, since the lattice permits the

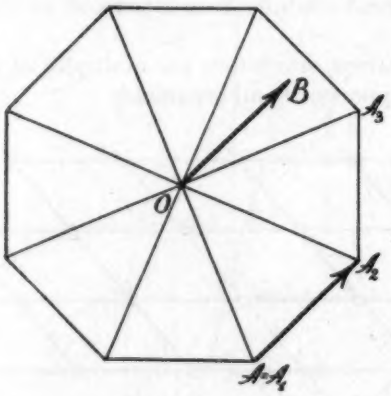

Fig. 6.—Octagon.

rotation by 180°, the smallest rotation leaving it invariant must be an aliquot part of 180°, or of the form

360° divided by 2 or 4 or 6 or 8 . . . .

We must show that the numbers from 8 on are impossible. Take the case $n=8$ and let A be one of the lattice points nearest to O. Then the whole octagon $A=A_1$, A_2, . . . consists of lattice points. The side A_1A_2 is smaller than OA just because $8>6$. Draw the vector $\overrightarrow{OB}=\overrightarrow{A_1A_2}$. O, A_1, A_2 being lattice points, B should be one too. However, this leads to a contradiction as B is nearer to O than $A=A_1$.

I beg your pardon. Did it hurt? The tooth is out now, and no such complicated geometric argument will come up again in this lecture. The rest shall be done more in the form of a narrative.

(2) How do lattices look which have one of our ten groups as their symmetry group? I enumerate the various cases.

C_1 and C_2: a perfectly arbitrary lattice L.

G_1 and G_2: either an arbitrary rectangular lattice R' or the diamond lattice R'' arising from R' by adding the centers of the rectangular meshes. R'' is the one most used for wallpapers.

C_4 and G_4: the square lattice Q.

C_3, C_6, G_3 and G_6: the hexagonal lattice H made up by equilateral triangles, which is in frequent use for tiled floors (bath rooms).

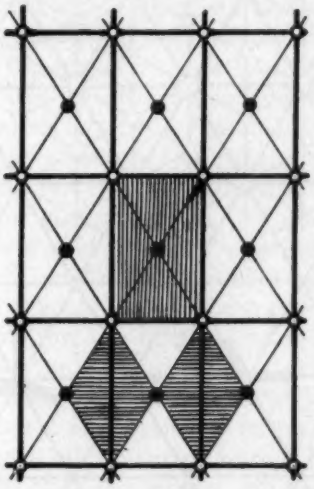

Fig. 7.—Rectangular and diamond lattice

Thus we encounter five types of lattices which differ by their symmetry. As an illustration I describe the full symmetry of the hexagonal lattice (upper half of Fig. 8). The points marked ● △ ⬡ are poles of multiplicity 2, 3, 6 respectively. The 6-poles form the lattice. All the lines are axes; the mid-lines between any two of these parallels are the gliding axes.

Finally we return from the reduced transformations, the rotary parts which form the group f_o, to the transformations proper. The translatory parts must dovetail with the lattice L of symmetry f_o. A closer investigation shows that the number 10 of possibilities is thereby increased to 17. *There are 17 essentially different kinds of symmetry possible for a two-dimensional ornament.* Examples for all 17 groups of symmetry are found among the decorative patterns of

antiquity, in particular among the Egyptian ornaments. One can hardly over-estimate the depth of geometric imagination and invention reflected in these patterns; their construction is far from being mathematically trivial. The art of ornament contains in implicit form the oldest piece of higher mathematics known to us. To be sure,

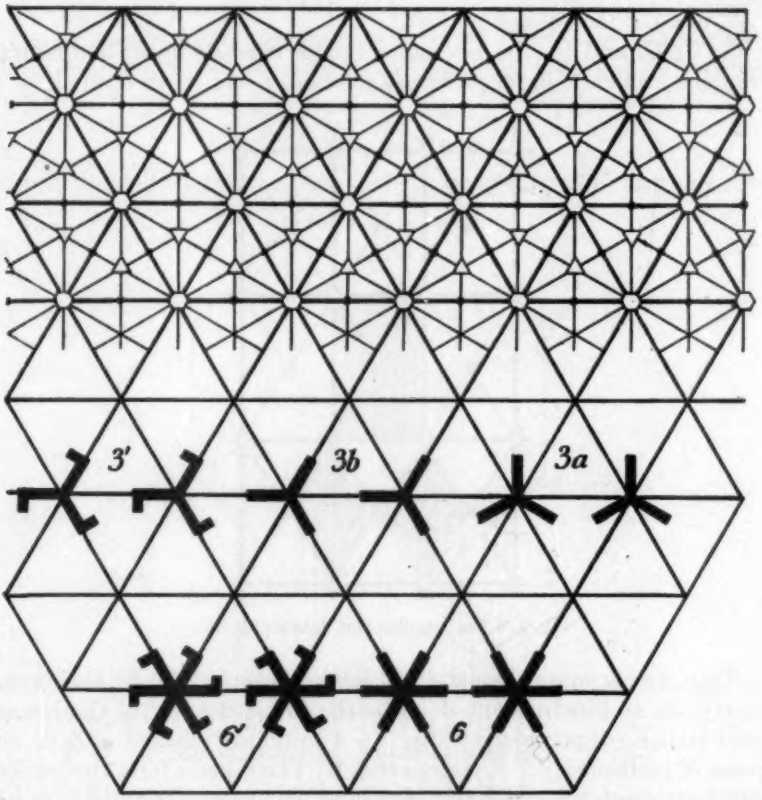

Fig. 8.—Hexagonal lattice and hexagonal symmetries.

the conceptional means for a complete abstract formulation of the underlying problem, namely the mathematical notion of a transformation group, was not provided before the 19th century; and only on this basis is one able to prove for good and all that the 17 symmetries already known to the Egyptian craftsmen more than 4000 years ago exhaust all possibilities. Strangely enough the proof was

carried out only as lately as 1924 by Professor Pólya in Zürich. The Arabs fumbled around much with the number 5, but they were of course never able honestly to build in a central symmetry of 5 in their ornamental designs. They tried, however, all kinds of deceptive compromises. One might say that they proved experimentally the impossibility of the pentagon in an ornament.

I shall discuss briefly the five ornamental symmetries of the hexagonal type. I represent them by simple patterns which I obtain by fixing simple starlike figures in the lattice points, the same in the same orientation at each point (lower half of Fig. 8). Here they are: 6 has the complete symmetry of the lattice itself (reduced group or class C_6). 6′ removes the symmetry axes (class G_6). 3*a*, 3*b*, 3′ reduce the 6-poles to triple poles, 3′ without symmetry axes (class G_3) while the class C_3 now breaks up into two subcases: in 3*a* axes pass through every 3-pole, in 3*b* only through those (⅓ of the whole number) which had been sixfold before. A wonderful example of the full symmetry 6 is this window of a mosque in Cairo, of the 14th century. The elementary figure is a trefoil knot the various units of which are interlaced with superb artistry. The gliding axes are particularly conspicuous; they are the mid-lines of the tracks. Axes are absent in this azulejos ornament from the Sala de Camas of the Alhambra in Granada; the group is 3′ or 6′ according to whether or not one takes account of the colors. This is one of the finer tricks of the ornamental art, that the symmetry of the geometric pattern as expressed by a certain group f is reduced by the coloring to a lower symmetry expressed by a subgroup of f. The picture will give you at the same time some idea of the fascinating total effect of the Moorish ornamental architecture. An example of 3*b* is provided by this simple Chinese ornament. I give one case of the square class G_4, the one exhibited by the well-known design (Fig. 9) for pavements. The amusing thing about it is that no ordinary axes, only gliding axes, pass through the 4-poles (one of which is marked). Here are two more refined samples of the same symmetry from the Alhambra again. If your interest in ornaments is aroused I should recommend that you go to the library and look into the great folios edited by Owen Jones in London about the middle of the last century—his "Grammar of Ornament" and the "Plans, Elevations, Sections and Details of the Alhambra" in two volumes.

The two-dimensional case has detained us long enough; we must now pass to the *three-dimensional space*. First again, symmetry around a center. The situation here is radically different from the plane.

While in the plane we have a regular polygon for each number n of sides, there are only *five regular polyhedra* in space: tetrahedron, octahedron, cube, pentagon-dodecahedron, and icosahedron. The Greeks were familiar with the five regular bodies. They played an eminent rôle in Plato's philosophy of nature. The discovery of the icosahedron and of the dodecahedron is certainly one of the most beautiful and singular discoveries made in the whole history of mathematics. In Euclid's elements their construction is one of the chief goals of the

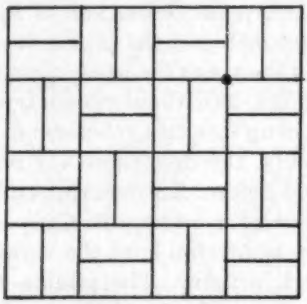

Fig. 9.—Pavement design.

whole development, perhaps *the* goal for the attainment of which all these efforts to erect a deductive system of geometry had been undertaken. It is the more surprising that the general notion of and a word for symmetry in our modern sense seems to be wanting in Greek. Euclid himself uses the word σύμμετρος in the sense of commensurable; side and diagonal of a square are ἀσύμμετρα μεγέθη. In the ancient non-mathematical literature σύμμετρος means as much as harmonious. Kepler in his Mysterium Cosmographicum, published in 1595, a long time before he discovered the three laws bearing his name today, made an attempt to reduce the distances in the planetary system to regular bodies which are alternately inscribed and circumscribed to spheres. Here is his construction by which he is convinced to have penetrated deeply into the secrets of the Creator. He proclaims his faith in prophetic words. We still hold to his belief in a mathematical harmony of the universe; it has stood ever wider and more surprising tests. But we no longer seek the harmony in static forms like the regular bodies, but in dynamical laws.

From our viewpoint the problem of the regular bodies is closely bound up with the construction of all finite groups of proper rotations

around a center. First we have again C_n whose operations are now interpreted in space as rotations around an axis perpendicular to our original plane. Rotations in space have an axis, reflections have a symmetry plane. Another possibility is G_n, where the reflections in the axes l_1, l_2, . . . in the plane are now interpreted as rotations by 180° about the same axes in space. Except for these relatively trivial cases in infinite number ($n = 1, 2, 3, \ldots$) already familiar to us from our study of the two-dimensional case, there are only three more quite singular possibilities:

The group T of the proper rotations carrying a tetrahedron into itself; the same group P for the octahedron or the cube (they are identical); the same group I for the icosahedron or the dodecahedron (they are again identical).

The orders of these groups are 12, 24, 60, respectively. It is not difficult to extend the table so as to include the presence of *improper* rotations. If no axes of rotation are admissible except of order 1, 2, 3, 4, and 6, we are left with 32 different groups.

They are the reduced groups or classes for a 3-dimensional ornament with a triple infinite rapport. Pasting the translatory onto the rotary parts, we obtain 230 *symmetry groups* which are divided into our 32 *classes*. The numbers we have found are collected in the following table for the dimensionalities 1, 2, 3:

Dim	No. of Classes	No. of Symmetry Groups
1	1	2
2	10	17
3	32	230

We decorate surfaces with flat ornaments; art has never gone in for *solid* ornaments. But they are found in nature. The arrangements of *atoms in a crystal* are such patterns. Unfortunately I have no models here, but I show you a photograph of two models (of calcite and rock-salt). The models consist of little balls representing the atoms and painted white, black, red, . . . according to the different sorts of atoms—hydrogen, carbon, oxygen, etc. The whole arrangement permits a group of motions with three independent translations spanning a lattice. The group describes the *microscopic symmetry of the crystal* ascertainable only by some device which allows discernment of distances of the order of the atomic distances, i.e., about 10^{-8} cm. How this has been accomplished I shall explain in a moment. The reduced

group or *class*, however, describes the *macroscopic symmetry* of the crystal which rules over all its macroscopically discernible properties, and hence may be observed without penetrating into the atomic structure. Physical quantities like compressibility, index of refraction, etc., of a crystal medium, depend in general on *direction*. The variation of the optical properties with direction gives a diamond its scintillating brilliance. We represent such a quantity graphically by laying off on each ray from a center O the value of the quantity in this direction. This diagram must have the symmetry around O as described by the reduced group. Conversely, in studying the dependence of all physical properties of a crystal on direction, we find out its reduced group. Hence the division of all crystals into 32 classes. One of the properties, the speed of growth, determines under ideal conditions the outward shape of a crystal which will thus conform to its inner symmetry. All of you have probably at some time examined snowflakes closely, perhaps even under a magnifying glass, and have been thrilled by their beautiful tiny hexagonal stars. The crystallographers have carefully and thoroughly investigated the symmetry groups in space for more than a century. Nobody in science, however, had cared much about the simpler two-dimensional case so important in the art of ornament, the mathematical study of which had thus been neglected until quite recently. This two-fold application in art and physics, to ornaments and crystals, constitutes a peculiar charm of our subject.

The assumption of a lattice-like structure of the crystals had been inferred from the crystallographic laws for a long time before von Laue twenty-five years ago discovered the key that actually opens up to us the atomic pattern. We see by *light*, but light has a certain wave length, and an image traced by such light will be fairly faithful only with respect to details of considerably greater dimensions than the wave lengths, while details of much smaller dimensions will be completely leveled down. The wave length of ordinary light is about 1000 times as big as the atomic distances. However, X-rays are of the same physical nature as light, and their wave length is exactly of the desirable order 10^{-8} cm. Hence X-ray pictures of a crystalline substance betray their internal atomic structure. In this way von Laue killed two birds with one stone: he confirmed the lattice structure of crystals, and proved what had been but a tentative hypothesis at that time, that X-rays consist of short-wave light. I show you two *Laue diagrams:* one of zinc-blende from Laue's original paper, 1912;

the other of carborundum (SiC) from a paper by H. Ott, 1926. The directions in which the pictures are taken are such as to exhibit the fourfold and the threefold symmetry respectively around an axis. You must not take these portraits of the interior of a crystal too literally. By observing a slit whose width is only a few wave lengths, you obtain a somewhat contorted image of the slit made up by interference fringes. In the same sense these pictures are interference patterns of the atomic lattice. However, one is able to compute from such photographs the actual arrangement of the atoms, the scale being set by the wave length of the illuminating X-rays.

In spite of all contortion which mars our X-ray likenesses, the symmetry of the crystal is faithfully portrayed. This is a special case of the following general principle: *If conditions which uniquely determine their effect possess certain symmetries, then the effect will exhibit the same symmetries.* Thus Archimedes concluded *a priori* that equal weights balance in scales of equal arms. Indeed the whole configuration is symmetric with respect to the mid-plane of the scales, and therefore it is impossible that one scale mounts while the other sinks. For the same reason we may be sure that in casting dice, which are perfect cubes, each side has the same chance,—one-sixth. Sometimes we are thus enabled to make predictions *a priori* on account of symmetry for special cases, while the general case, as for instance the law of equilibrium for scales with arms of different lengths, can only be settled by experience or by physical principles ultimately based on experience. As far as I see, all *a priori* statements in physics have their origin in symmetry.

With this remark I shall conclude the somewhat detailed discussion of geometric symmetries dwelling in ornaments and crystals. I now take to the air and give a quick bird's eye view of other important applications of symmetry in physics and mathematics. First, *relativity theory.* Relativity is simply the most fundamental instance of symmetry. Before we studied geometric forms in space with regard to their symmetry, we should have examined *space itself.* Empty space possesses a very high grade of symmetry. On account of its homogeneity, all points are alike; there is no objective geometric property by which one may distinguish one point from any other. They can be distinguished only by a demonstrative act, by pointing with the finger and saying "*here.*" In the same sense all directions at a point are alike. The full homogeneity or symmetry of space must be described again by its group of automorphisms. A point transformation

$\left\{ \begin{matrix} p \to p' \\ p' \to p \end{matrix} \right\}$ in space is an automorphism if it leaves untouched every imaginable objective geometric relation between points. For instance, $R(p_1p_2p_3)$ being any such ternary relation like that expressed in the words: $p_1p_2p_3$ lie on a straight line, we require that any three points satisfying this relation R are turned by the automorphism into three points $p_1'p_2'p_3'$ fulfilling the same relation. Relativity is nothing else than the problem of *determining the group of automorphisms of space itself*. Two figures arising from each other by an automorphism are called "*similar*" in geometry; they are, as Leibnitz said, indiscernible when each is considered by itself and not in their mutual relation. The automorphisms of a given geometric pattern which we investigated before, may now be described in more basic terms as the *automorphisms of space carrying the given pattern into itself*. When we draw a regular hexagon around a point O in the plane, then no longer are all directions from O alike with respect to the hexagon, but merely any six directions forming a hexagonal star. The problem of relativity for the four-dimensional world including time besides the three dimensions of space, was solved in a final manner by Einstein. Felix Klein in his famous Erlanger Program, 1872, classified the various types of geometries, such as metric, affine, projective, conformal geometry, etc., by their groups of automorphisms which are either given by nature or agreed upon by convention. *Geometry*, as Klein declared, *is the study of an arbitrary set of elements called points under the viewpoint that only such relations are taken into account as are invariant under a given group of point transformations*, which then play the rôle of automorphisms.

By far the most fertile application of symmetry in the whole inorganic world has been made by *quantum physics* in studying the *atomic and molecular spectra*. An enormous amount of empiric material concerning the spectral lines, their wave lengths, and the regularities in their arrangement, had been collected before quantum physics was able to order the vast material and to show that most of the laws, whether of qualitative or quantitative nature, are independent of all dynamic peculiarities and assumptions, and a simple consequence of the inherent symmetry. Let us consider an atom consisting of a cloud of n electrons moving around a fixed nucleus at O. (By assuming the nucleus to be fixed we neglect the reaction of the electrons upon the much heavier nucleus.) The symmetry prevailing is twofold. First, rotational symmetry around O; two positions of the electrons which arise from each other by turning the whole constellation like a rigid

body about O are indiscernible. This symmetry is expressed by the group of geometric *rotations* in space. Second, all electrons are alike; this symmetry is expressed by the $n!$ *permutations* among the n electrons: two constellations arising from each other by such a permutation are indiscernible. I cannot describe here in more detail how these two simple facts lead to the ordering of the atomic spectra; you must believe me on my word that nowhere else has symmetry proved the clue to a field of greater variety and importance.

Finally I turn to *mathematics*, which I must include all the more because the essential concepts, especially that of a group, were first developed from the applications in mathematics, more particularly in algebra and the theory of algebraic equations. An algebraist is a man who deals in numbers, but the only operations he is able to perform on them are the four species $+, -, \times, \div$. Hence the only relations he can grasp with his methods are the algebraic relations expressible in terms of these operations; as, for instance, the following one between two numbers α and β:

$$\{\ \beta^2+\alpha(5\beta-2)\ \}^3-9\alpha+1+3\alpha\beta^4=0.$$

Let us consider any finite set of numbers $\alpha_1, \cdots, \alpha_n$, in particular the roots of an algebraic equation of degree n. Transformations are here permutations of the n numbers α_i; an automorphism is a permutation leaving untouched every imaginable *algebraic* relation among them. The automorphisms among the roots of an algebraic equation form the so-called *Galois group;* Galois's theory is nothing else than the relativity theory for this set which, by its discrete and finite character, is conceptually so much simpler than the infinite set of points in space dealt with by ordinary relativity theory. Galois's ideas, which for several decades remained a book with seven seals but afterwards exerted a more and more profound influence upon the whole development of mathematics, are contained in a farewell letter to a friend written on the eve of his death, which he met in a duel at the age of twenty-one. This letter is the most substantial piece of writing I know in the whole literature of mankind. I give two simple examples of Galois's theory.

The ratio $\sqrt{2}$ between diagonal and side of a square is determined by the quadratic equation

$$x^2-2=0.$$

Their incommensurability, that is, the fact that $\sqrt{2}$ is not a rational number, means that the two roots $\sqrt{2}$, $-\sqrt{2}$ are algebraically indistinguishable, or that their exchange is an automorphism. This is the

instance by which the Greeks discovered the *irrational.* The deep impression which its discovery by the Pythagoreans made upon the thinkers of antiquity, is evidenced by a number of passages in Plato's Dialogues.

My other example is Gauss's construction of the regular 17-gon with ruler and compass, which he found as a young lad of nineteen. Up to then he had vacillated betweeen philology and mathematics; this success was instrumental in bringing about his final decision in favor of mathematics. When one fixes one vertex of an n-gon, all the other $n-1$ are the roots of an algebraic equation of degree $n-1$. They are algebraically indiscernible provided n is a prime number like 17, and the automorphisms then form a cyclic group of order $n-1$, i.e. a group that may be depicted by dialing a circular dial with $n-1$ equidistant marks. Since

$$17-1=16=2\times2\times2\times2$$

is a power of 2, one can cut down the cyclic group in passing from group to subgroup, by four consecutive steps, to the orders 8, 4, 2, 1. The solution of our equation of degree 16 is then obtained by means of four consecutive solutions of quadratic equations, or by four consecutive extractions of square roots. However, the four species and extraction of a square root are exactly those algebraic operations which may geometrically be carried out by *ruler and compass.* This is the reason why the regular triangle, pentagon and 17-gon,

$$3=2^1+1,\quad 5=2^2+1,\quad 17=2^4+1,$$

may be constructed by ruler and compass. ($2^3+1=9$ must be skipped because 9 is not a prime number.) During the last decades algebra has thriven more vigorously than most other branches of mathematics. For all the manifold structures it has to deal with, the quest for the group of automorphisms has always proved of cardinal importance and led straight to the core of things. One of the chief accomplishments of the late great algebraist Emmy Noether was her insistence upon this idea and the many applications she made of it in all branches of algebra.

I hope I have succeeded in giving you an impression of the deep significance of the principle of symmetry in art, nature and mathematics. Symmetry always stands for a peculiar kind of perfection. No wonder, therefore, that mystics and theologians have made use of this word and notion to describe by analogy even God's own perfection. I conclude with a short poem by Anna Wickham:

God, Thou great symmetry,
Who put a biting lust in me
From whence my sorrows spring,
For all the frittered days
That I have spent in shapeless ways
Give me one perfect thing.

PALEONTOLOGY.—*A Paleocene mammalian fauna from central Utah.*[1] C. LEWIS GAZIN, U. S. National Museum.

In 1935, while making geological investigations in the region of the Wasatch Plateau in central Utah, for the U. S. Geological Survey, Dr. E. M. Spieker and Dr. J. B. Reeside, Jr., discovered dinosaur and indeterminable mammalian remains in beds which had heretofore been considered as "Wasatch" in age. As a result of these discoveries a Smithsonian Institution party in 1937, under the direction of Mr. C. W. Gilmore, and with the aid of Dr. Spieker, made a more thorough investigation of the beds with highly profitable results. In addition to material representing a variety of reptilian forms the party was successful in securing a number of more or less fragmentary specimens of Paleocene mammals. The latter were discovered in beds immediately overlying the Cretaceous dinosaur levels but lithologically a part of the same sequence which Dr. Spieker has named the North Horn formation. The mammal bearing level is in variegated beds in the upper part of the formation just below the Flagstaff limestone, the localities investigated being in the vicinity of North Horn Mountain, southwest of Price, Utah.

A study of the mammalian material, which includes 16 specimens having one or more teeth, indicates that the fauna is more recent than Puerco, though apparently older than Torrejon, as the faunas of these formations are known from the San Juan Basin in New Mexico. In addition to a crocodile, six mammalian forms are distinguished in the collection. These are as follows:

INSECTIVORA
Aphronorus simpsoni, n. sp.
Insectivore?, gen. & sp. undet.
CARNIVORA
Protogonodon? spiekeri, n. sp.
Chriacus? sp.

[1] Published by permission of the Secretary, Smithsonian Institution. Received March 23, 1938.

TALIGRADA
Periptychus gilmorei, n. sp.
CONDYLARTHRA
Hyopsodont, gen. & sp. undet.

The presence of *Aphronorus* and a hyopsodont, which is near *Litaletes*, in the fauna suggests a relationship with the Crazy Mountain Fort Union fauna but as these forms are known only from the Fort Union facies little can be said concerning their development or geologic range.

The principal evidence for the age of the fauna is found in the material of *Periptychus gilmorei* and *Protogonodon? spiekeri*. These forms represent better known groups whose geologic history is somewhat better understood. The periptychid is clearly intermediate in almost all characters between *Carsioptychus coarctatus* of the Puerco and *Periptychus carinidens* of the Torrejon. Similarly, the large creodont is intermediate between *Protogonodon pentacus* and *Claenodon corrugatus* (*C. ferox*) of the two San Juan horizons. This interpretation is not entirely conclusive as the relationship can be established only after a greater representation of the fauna is known, but from the material at hand an age intermediate between Puerco and Torrejon seems evident.

Inasmuch as it seems desirable to use a separate name to designate this fauna, for distinguishing it from the underlying Cretaceous dinosaurian fauna, and from other Paleocene faunas, the writer proposes the name Dragon (suggested by Dr. Spieker), from the canyon in which the fossils were found. The writer fully recognizes the difficulties which would be encountered in attempting to define on a lithologic basis the beds in which this Paleocene fauna occurs. Field work by Dr. Spieker has shown that the North Horn formation is a lithologic unit in which no disconformity or other structural evidence is apparent on which one can satisfactorily separate the two sets of beds. A marked interval of time between the two faunas is indicated, however, and similar situations are known to exist in the relations between other successive faunal zones, such as between the classic horizons, Puerco and Torrejon, in the San Juan Basin of New Mexico. Hence, it is not without precedent that a geographic name is used to designate a fauna, if only to serve as a handle for paleontological use.

The writer wishes to acknowledge the courtesy extended by Dr. G. G. Simpson in making helpful suggestions and in permitting comparisons with Paleocene materials in the American Museum.

SYSTEMATIC DESCRIPTION OF MATERIAL

INSECTIVORA

Aphronorus simpsoni, n. sp.

Holotype.—Left ramus of mandible, U.S.N.M., no. 15539, with P_4–M_3 (Fig. 1).

Locality.—N. W. ¼ sec. 8, T. 19 S., R. 6 E., Emery County, Utah.

Horizon.—Dragon, Paleocene.

Specific characters.—Ramus slightly deeper than in *Aphronorus fraudator*. Teeth relatively more slender in anterior portion. Posterior teeth relatively larger. Posterior wall of trigonid in molars directed slightly more forward externally.

Description.—*Aphronorus simpsoni* is close in size to *A. fraudator* Simpson from the Crazy Mountain Fort Union, but differs from this species in certain relative proportions which are outside the limits given by Simpson for the middle Paleocene form. The ramus is slightly deeper than in the several

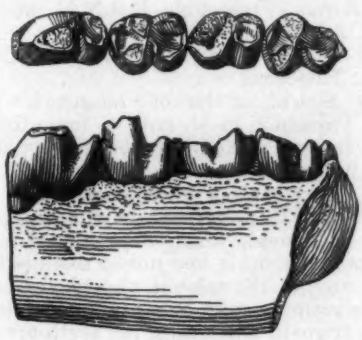

Fig. 1.—*Aphronorus simpsoni*, n. sp. Left ramus of mandible with P_4-M_3, type specimen, U.S.N.M. No. 15539. Lateral and occlusal views. ×4. Dragon Paleocene, Utah. Drawing by Sydney Prentice.

Fort Union specimens which the writer examined, a difference which is more noticeable in the posterior portion. Also, the posterior molars are relatively larger, particularly M_3, which is larger than in any of the Fort Union specimens examined. However, the teeth are relatively slender. This is most noticeable in P_4 which combines the greatest length with the least width given by Simpson for *A. fraudator*. Moreover, the posterior wall or shear of the trigonid in the molars is not so distinctly transverse, but directed slightly more forward externally. In P_4 the shear is more nearly transverse though somewhat irregular as a slight ridge extends down the posterior wall of the metaconid and unites with the hypoconid crest.

In addition to the holotype there are three isolated lower teeth, which are tentatively referred to this species.

Insectivore?, gen. & sp. undet.

A jaw fragment with only M_3 preserved may represent a second insectivore in the fauna. The tooth is about the size of that in *Aphronorus simpsoni*

TABLE 1.—MEASUREMENTS OF LOWER TEETH OF *Aphronorus simpsoni*

	P_4	M_1	M_2	M_3
Anteroposterior diameter	3.8 mm.	3.0	3.0	3.2
Transverse diameter	2.0	2.1	2.2?	2.2

but shows a somewhat different construction. The hypoconid and hypoconulid are more widely separated and a slight cingulum is present around the outer wall from about the parastylid to the hypoconulid. The tooth is not greatly different from that in the Puerco hyopsodont, *Oxyacodon priscilla*, but the paraconid is placed too far lingually and the hypoconulid is not so well developed.

CARNIVORA

Protogonodon? spiekeri, n. sp.

Holotype.—Right ramus of mandible, U.S.N.M. no. 15538, with M_1, M_2 and part of M_3 (Fig. 2).

Locality.—N. W. ¼ sec. 8, T. 19 S., R. 6 E., Emery County, Utah.

Horizon.—Dragon, Paleocene.

Specific characters.—Size about that of *Protogonodon pentacus*. Enamel on molars more rugose. Paraconid in M_1 and M_2 more lingual in position and slightly less distinct from metaconid. Entoconid apparently more distinct from hypoconulid in M_1 to M_3.

Description.—The lower molars of *Protogonodon? spiekeri* correspond closely in size to those of *P. pentacus* from the Puerco, but exhibit more rugose enamel. The paraconid, which is preserved in only the first two molars, is more lingual in position and not so distinct from the metaconid. However, the cusps around the talonid, though low, are somewhat more distinct from those adjacent than in *P. pentacus*, with less development of a crest and basin. The trigonid portions of the teeth are somewhat more elevated with respect to the talonids than is usual in *P. pentacus*.

In the reduction and position of the paraconid and in the rugosity of the enamel the Dragon form makes a definite approach toward the condition seen in the Torrejon specimens referred to *Claenodon corrugatus* (*C. ferox*). The paraconid in M_3, and perhaps M_1, of *Protogonodon? spiekeri* is better developed and more distinctly separated from the metaconid than in *C. corrugatus* although it is placed nearly as far lingually as in the Torrejon material. The union or ridge between the protoconid and metaconid is simple and not double as frequently seen in the more coarsely rugose teeth of *Claenodon corrugatus*. On the talonid the hypoconulid is more distinct from the entoconid, whereas in *Claenodon corrugatus* these two form a more conspicuous ridge which usually continues with the cingulum around the hypoconid. The cusps in general are lower and more distinct than in *Claenodon*, with a less distinctly basined talonid, with fewer accessory cuspules, and a finer quality of rugosity.

M_3, though incomplete, is much less elongate than in *C. corrugatus*, as indicated by the spacing of the metaconid, entoconid, and hypoconulid.

A maxillary fragment with part of M^3 and the root portion of M^2 shows no important characters other than a relatively great difference in size between these two teeth.

In most respects, especially in the character of the trigonid of the lower

molars, *P.? spiekeri* stands in a relation nearly intermediate between *Protogonodon* and *Claenodon*, with perhaps a slightly greater resemblance to *Protogonodon*. It is distinct from the Fort Union *Deuterogonodon montanus*, as represented by the paratype, in the lowness of the cusps, the far less developed crest and basin of the talonid, and in the relatively greater importance of the entoconid as compared with the hypoconulid.

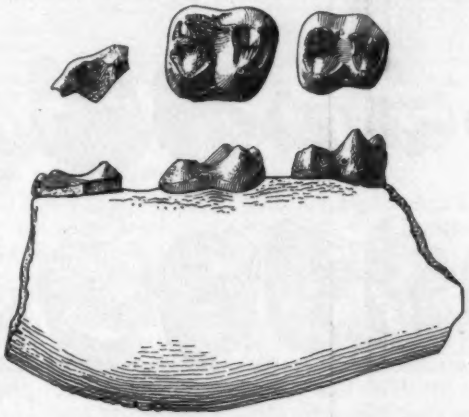

Fig. 2.—*Protogonodon? spiekeri*, n. sp. Right ramus of mandible with M_1, M_2, and part of M_3, type specimen, U.S.N.M. No. 15538. Lateral and occlusal views. ×1½. Dragon Paleocene, Utah. Drawing by Sydney Prentice.

The anteroposterior diameters of the first and second lower molars are 10 and 11 mm respectively. The transverse diameters are 8 and 9.3 mm.

Chriacus? sp.

An isolated second upper molar and a maxillary fragment with a well worn first molar and part of the second represent an oxyclaenid carnivore, apparently near *Chriacus*. The teeth are about the size of those in *Chriacus baldwini*. The cusps are somewhat more conical than in *Chriacus* though not so rounded as in *Tricentes*. The inner portion of the isolated tooth shows a moderately developed hypocone, more lingual in position than in *Tricentes*, and a slight protostyle. The cingulum is interrupted for a very short distance between the hypocone and the protostyle. The protoconule and metaconule are less markedly joined to the paracone and metacone respectively than in *Chriacus* or *Metachriacus*. The Utah material is near that of *Metachriacus* but the cingulum is not so developed around the protocone as in the Fort Union form.

TALIGRADA

Periptychus gilmorei, n. sp.

Holotype.—Right and left maxillae, U.S.N.M. no. 15537, with cheek teeth P^2–M^3 (Fig. 3).

Locality.—N. W. ¼ sec. 8, T. 19 S., R. 6 E., Emery County, Utah.

Horizon.—Dragon, Paleocene.

Specific characters.—Size near that of *Periptychus carinidens*. Upper cheek teeth relatively wider. Lingual portion of upper premolars somewhat more constricted anteroposteriorly. Lingual wall of premolars and molars more gently sloping. External cingulum of molars better developed and cusps closer together. Inner crescent of upper premolars more fully developed than in *Carsioptychus coarctatus*. Apparently the talonids of the lower premolars (as indicated by a referred specimen) are better developed than in *C. coarctatus*.

Fig. 3.—*Periptychus gilmorei*, n. sp. Right maxilla with P^3-M^3, type specimen, U.S.N.M. No. 15537. Lateral and occlusal views. ×1½. Dragon Paleocene, Utah. Drawing by Sydney Prentice.

Description.—*Periptychus gilmorei* is intermediate between *Carsioptychus coarctatus* from the Puerco and *Periptychus carinidens* from the Torrejon in almost all characters of the upper dentition. The teeth are relatively wide transversely as compared with their length and the premolars are only slightly larger than the molars. The premolars show the inner crescent developed almost as much as in *Periptychus carinidens* but the deuterocone portion is more constricted anteroposteriorly although not so much as in *Carsioptychus coarctatus*. Moreover, P^2 is much more like that in *Periptychus* than the simple condition observed in several specimens of *Carsioptychus*.

The molar teeth show a distinct resemblance to those in *Carsioptychus*, and in addition to their being relatively wide transversely, show a more distinct external cingulum than in *Periptychus*. The hypocone and protostyle have a somewhat more lingual position and the lingual walls of the molars (and premolars as well) appear to be more gently sloping than in *Periptychus*. The cusps and cuspules are somewhat less widely spaced than in *P. carinidens*, particularly the protoconule and metaconule which are located very close to the protocone.

An additional feature in *Periptychus gilmorei*, but probably of no importance is the very slight development of a "protostyle" and "hypocone" on P^4. This was not observed in any of the Puerco or Torrejon material. Also, the third molar, on the right side only, is peculiar in that the lingual wall exhibits a cuspule median to the protocone, between the protostyle and hypocone.

In an incomplete, isolated, lower premolar from the Utah locality, prob-

ably representing *Periptychus gilmorei*, the development of the cusps on the talonid is more suggestive of *Periptychus* than of *Carsioptychus*.

TABLE 2.—MEASUREMENTS OF UPPER DENTITION OF *Periptychus gilmorei*

	P^2	P^3	P^4	M^1	M^2	M^3
Anteroposterior diameter	11.6 mm.	11.7	10.5	9.2	9.5	8.8
Transverse diameter*	12.7	14.6	14.0	14.2	14.1	11.1

* The transverse diameter is taken from the external cingulum to the base of the enamel lingually and at right angles to the direction of the tooth row.

CONDYLARTHRA

Hyopsodont, gen. & sp. undet.

Four isolated lower jaw fragments with one tooth each and a fifth specimen including two upper teeth and some parts of associated (?) lower teeth represent a hyopsodont condylarth related to *Ellipsodon*. The form probably represents a new genus near *Litaletes*, but the material is too fragmentary to permit adequate description.

The two upper teeth, apparently M^1 and M^2, both exhibit a distinct hypocone, which in M^2 is markedly lingual in position. Also, in M^2 there is a slight protostyle and the cingulum is almost continuous around the inner wall of the tooth. M^1 is somewhat smaller and relatively narrower transversely, does not have a protostyle, and the cingulum does not extend around on the lingual surface. The two upper molars resemble those in *Litaletes disjunctus* but the protocone, paracone, and metacone are somewhat more widely separated. Moreover, the more lingual position of the hypocone, the extent of the cingulum, and the presence of the protostyle in M^2 distinguish it from *Litaletes*. The anteroexternal and posteroexternal angles of the two upper molars are developed more as in *Litaletes* than as in *Ellipsodon*.

In the lower molars the paraconid is lingual in position as in *Ellipsodon*, *Litaletes*, *Mioclaenus*, *Choeroclaenus*, and *Tiznatzinia;* not as in *Protoselene*, *Oxyacodon* and *others*. The lower molars are much as in *Ellipsodon lemuroides* in size and appearance but with the protoconid and metaconid farther apart and the talonid somewhat less deeply basined.

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PALEONTOLOGY.—*Descriptions of a new genus and a new species of Carboniferous brachiopods.*[1] GEORGE H. GIRTY, U. S. Geological Survey.

The contribution to paleontologic literature which follows is so insignificant that I venture a few words of explanation or perhaps of apology.

The privilege was recently given to me of sharing in the re-description and re-illustration of the Paleozoic species treated by Roemer in his *Kreidebildung von Texas*. One of these (*Productus flemingi* Roemer von Sowerby) proved to be an undescribed species of *Marginifera* to which I gave the name *Marginifera roemeri*.[2] Now it was clearly in the interest of American Paleontology to base the species not upon Roemer's specimens, but upon specimens in my own collections which could be consulted by other paleontologists of this country. At the same time it was not consonant with the project in hand to describe or figure any specimens other than Roemer's own. Consequently, *Marginifera roemeri* has remained up to now a *nomen nudum* and it seemed desirable to remove it from that status as soon as possible.

Regarding the genus *Anopliopsis* little need be said. The description might well have awaited publication in a proper setting except that I wished to refer to the genus soon in a different connection. The genus is based upon a species which has been in the literature for several years as *Chonetina subcarinata* Girty.[3] The type specimens came from the Ridgetop shale and Fort Payne formation of western Tennessee and it may be of interest to recall that *A. subcarinata* has several times been identified as a species of *Ambocoelia*, a not unpardonable error inasmuch as ventral valves with their small size, high convexity and smooth surface strongly suggest the ventral valve of that genus.

Marginifera roemeri, n. sp. Figs. 1–5

Productus flemingii. Roemer von Sowerby, Kreidebildung von Texas, p. 89, pl. 11, figs. 8a, b, 1852. Carboniferous: San Saba Valley, Texas.

Ventral valve small, strongly transverse, widest at the hinge, hemispherical. The curvature is irregular longitudinally; the highest part of the valve is posterior to the middle and the curvature is somewhat stronger at that point than it is before or behind it. Umbonal region rather inflated. Auricles large and somewhat abruptly extended. Anterior slope with a sinus, which may be rather strong, extending backward to or onto the visceral disc.

Surface marked by radial costae which are fairly high and separated by rounded striae. The costae are rather coarse for the size of the shell. The

[1] Published by permission of the Director, Geological Survey, U. S. Department of the Interior. Received February 15, 1938.

[2] GIRTY, GEORGE H. U. S. Geol. Survey Prof. Paper **186-M**: 264. 1937.

[3] GIRTY, GEORGE H. U. S. Geol. Survey Prof. Paper **146**: 27. 1926.

distance from crest to crest is commonly 1 mm and about 6 costae, also from crest to crest, come within a space of 5 millimeters. This number may be increased by 2 or 3 if the measurement is taken where some of the full-sized costae have divided to form smaller ones. The visceral disc is marked by concentric corrugations which vary in character in different specimens. They may be rather numerous, strong and regular, or on the other hand rather weak and unequal. The entire surface is crossed also by strong, fine, incremental lines. Spines are fairly large but not numerous and they are without any noticeable differential arrangement. They form neither a distinct row along the hinge-line, as in many species, nor a distinct tuft on the auricles as in others.

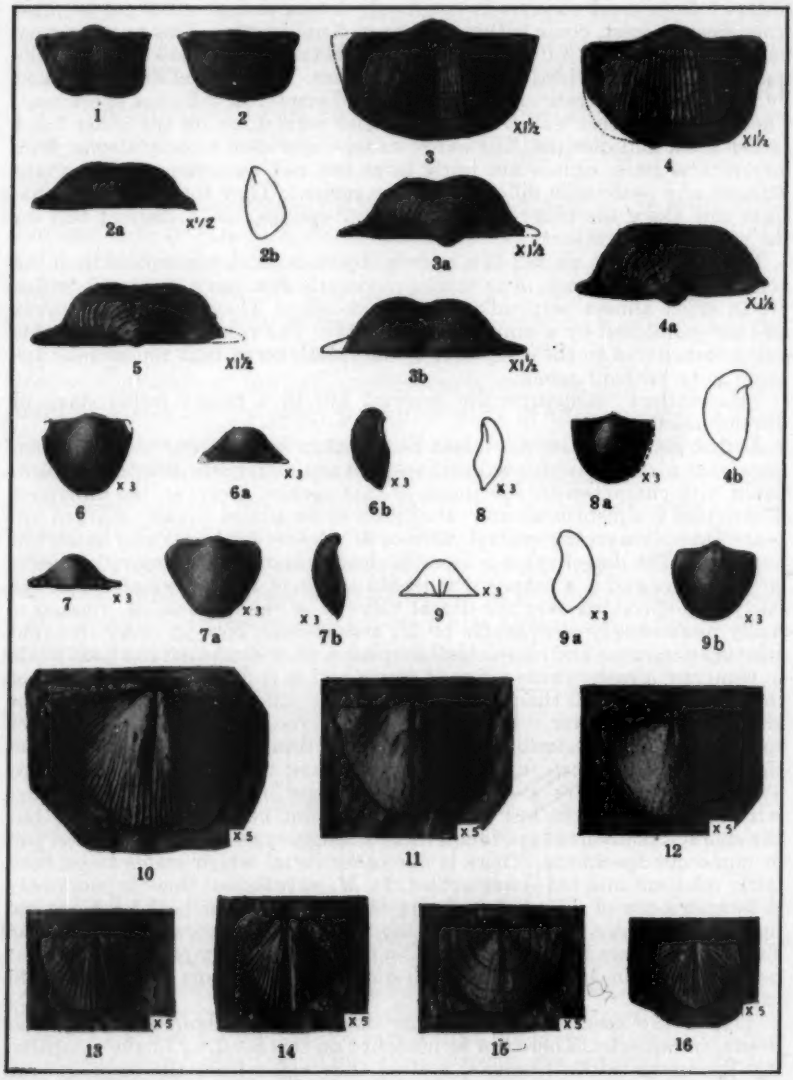
The dorsal valve, viewed as a convex object, is much less curved than the ventral valve. It consists of an extensive visceral disc and a short tail, which are in effect almost perpendicular to each other. They are gently convex and are connected by a much stronger curve. The other characters of this valve correspond to those of the ventral valve except that the surface appears to be without spines.

"*Marginifera*" structures are present, but in a rather feeble stage of development.

At first glance this species might be mistaken for *Marginifera muricatina*, somewhat more finely striated perhaps, but not materially different. If compared with characteristic specimens of that species, however, the difference in striation is conspicuous and other differences almost equally marked appear. The spines on the ventral valve of *M. roemeri* are larger and much less numerous. The dorsal valve is quasi-geniculate instead of being rather regularly concave and it is apparently devoid of spines, whereas small spines are fairly well sprinkled over the dorsal valve of *M. muricatina*. *M. roemeri* is really more closely comparable to *M. wabashensis*. Now in order to avoid creating numerous and impracticable species, *M. wabashensis* has been made to comprise a rather wide range of forms and it is difficult to select one of these as more typical than another or to name differences that will hold for all. Generally, however, it may be said that *M. roemeri* is a relatively broader species with a less convex ventral valve. The sinus is apt to be deeper than that of *M. wabashensis*, and the corrugations of the visceral disc stronger. The radial costae are also, as a rule, stronger, rising higher from wider striae. The differences last mentioned may not be so very constant, but the characters involved are found more strongly expressed in *M. roemeri* and in numerous specimens. There is one other detail which seems to be both fairly constant and not unimportant. In *M. wabashensis* there is commonly to be seen a row of spine bases passing obliquely from the beak to the lateral margins low down on each side of the vault. The spines are graduated in size, the final ones being very large. No feature really comparable to this has been observed in *M. roemeri*, though something of the sort appears sporadically.

This is the species which Roemer discussed and figured as *Productus flemingii*[4] Sowerby. There can be no doubt on this head, as I have compared my specimens with Roemer's, and as they come from the same general locality, and occur in the same faunal association. Bibliographers have commonly classed Roemer's form in the *Marginifera splendens-Wabashensis* series. Schuchert, for instance, places it under *Productus longispina* along with *M. splendens* and *M. wabashensis*. Weller also places it under *P. longispina* along with *M. splendens* but gives *M. wabashensis* separate recognition.

[4] ROEMER, FERDINAND. *Kreidebildung von Texas*, p. 89, pl. 11, figs. 8a, 8b. 1852. See also, GIRTY, GEORGE H. Geol. Survey Prof. Paper 186-M: 264. 1937.



Figs. 1–5.—*Marginifera roemeri*, n. sp. Fig. 1. A ventral valve with unbroken auriculations. Figs. 2, 2a, 2b. Three views of a dorsal valve preserved as an external mold partly covered by shell. Fig. 2a is enlarged ×1½. Figs. 3, 3a, 3b. Three views of a large ventral valve, all ×1½. Figs. 4, 4a, 4b. Three views of another ventral valve, all ×1½ except fig. 4b. Fig. 5. Posterior view of a ventral valve, ×1½. All the figured specimens of *Marginifera roemeri* came from the Smithwick shale (?), 11 miles west of San Saba, Texas (station 2602). (Legend continued on opposite page.)

As just stated, *M. roemeri* appears to find its nearest relative in *M. wabashensis;* it is widely unlike *M. splendens.*

Horizon and locality.—Smithwick shale (?), San Saba quadrangle, just south of highway eleven miles west of San Saba Courthouse, Texas (station 2602).

Anopliopsis, n. gen. Figs. 6–16

This genus may be summarily described as a small chonetid which has a highly arched ventral valve without a sinus and is superficially marked only by incremental lines without radial striation. Internally the ventral valve has a long and fairly strong septum; the brachial valve is covered as to the median part by a number of relatively high, thin radiating plates and as to the lateral parts by spinules.

The internal structure of the brachial valve is thought to be the main distinguishing feature of the genus. The configuration and surface characters may also prove to be diagnostic but to what extent will rest largely upon congeneric species when any are discovered. As a brief statement of its relations, *Anopliopsis* is distinguished from *Anoplia* by the presence of cardinal spines wherein it is exactly like *Chonetes.* It is distinguished from *Chonetes* by having the spinules on the interior of the brachial valve replaced over the median region by vertical plates, much as in *Chonetina.* It is distinguished from *Chonetina* by being smooth instead of striated and by having the pedicle valve strongly convex on the median line instead of deflected inward to form a deep sinus.

Genotype.—*Anopliopsis subcarinata* Girty.

The species which is here made the basis of a new genus was originally described under *Chonetina* Krotow.[5] The departure from that assignment does not mark so complete a reversal of opinion as it might appear to do for the reference to *Chonetina* was more or less qualified and the new genus is not proposed without some reservations.

Chonetina subcarinata was described in connection with a small fauna of Boone age from San Saba County, Texas, but the description was based upon specimens from the Ridgetop shale and the Fort Payne formation, in

[5] GIRTY, GEORGE H. U. S. Geol. Survey Prof. Paper 146: 27, pl. 5, figs. 10a–16. 1926. By oversight the generic heading is *Chonetes* but the species is described as *Chonetina subcarinata.*

Figs. 6–16.—*Anopliopsis subcarinata* Girty. Figs. 6, 6a, 6b. Three views of a ventral valve, ×3. Figs. 7, 7a, 7b. Three views of another ventral valve, ×3. Figs. 8, 8a. Two views of another ventral valve, ×3. Figs. 9, 9a, 9b. Three views of a characteristic ventral valve, ×3. Fig. 10. Internal mold of a ventral valve in which the lamellose character is strongly developed, ×5. Fig. 11. Internal mold of a ventral valve in which the same character is faintly developed or poorly preserved, ×5. Fig. 12. External mold of a dorsal valve. The silicified fillings of the cardinal spines of the ventral valve can be seen above, ×5. Figs. 13 and 14. Squeezes made from the internal molds of two dorsal valves, ×5. Fig. 15. External mold of a dorsal valve, ×5. Fig. 16. Like figures 13 and 14, a squeeze made from an internal mold of a dorsal valve, ×5. All the specimens figured came from localities in the Waynesboro quadrangle, Tennessee, and all but the original of fig. 7 (which was collected in the Ridgetop shale) came from the basal part of the Ft. Payne chert. The specimens shown by figs. 6 and 8 came from station 1822; that shown by fig. 7 came from station 1853; those shown by figs. 9 and 14 came from station 1821; that shown by fig. 10 came from station 1830; that shown by fig. 11 came from station 1826; those shown by figs. 12, 13, 15, 16, came from station 1841. Figures 6, 6a, 6b, 8, 8a, 9, 9a, 9b, are the original figures used when the species was published as *Chonetina subcarinata.* In addition to these specimens from Tennessee on which the species was founded there were also figured at that time a specimen from the Moorefield shale of Oklahoma and 3 specimens from rocks of Boone age in Texas.

the Waynesboro quadrangle in western Tennessee; the same species occurs in the Moorefield fauna of northeastern Oklahoma. All three of the figured specimens (figs. 10–12) were ventral valves. As the internal characters of the dorsal valve are so important from a generic standpoint, I propose to figure specimens of that valve, some showing the inner, others the outer surface, and for the convenience of the reader I propose to give a resume of the characters of both valves, so far as known.

Externally the shell in certain respects agrees with *Chonetes* for it is concavo-convex, it has a cardinal area in both valves, and it has cardinal spines issuing from the ventral valve. Internally also it has certain characters in common with *Chonetes*. It is provided with dental plates and sockets and the dorsal valve has a small cardinal process, its outer surface divided by two (?) incisions. The details of this very small structure cannot be given nor has it been ascertained whether it is partly covered by a "cheilidium."

The ventral valve has a fairly long, stout, median septum in the form of a ridge more or less sharp on top but spreading downward to merge by degrees with the contour of the interior. Whether this structure should be called a septum is open to question, for it is rather an angular ridge than a thin plate such as is often designated by that term. The answer to this question would depend upon how a "septum" was defined and whether the wedge-shaped ridge was originally a thin plate which had reached its present shape through depositions of callus along its sides. The septum of *Anopliopsis* does seem to be thin and high at the tip of the beak and is probably something more than a mere accumulation of callus. It differs from the septum of *Chonetes* in length as well as in its shape, the septum in *Chonetes* being a thin plate and present, in this character, only in the umbonal region.

There is, however, a certain lack of agreement among authors regarding the presence of a septum in the valves of *Chonetes*. Hall and Clarke, for instance, credit *Chonetes* with a septum in both valves. Weller does not mention a septum as present in either valve (I mean of course in his generic diagnosis); and the same may be said of Dunbar and Condra, though they, to be sure, were writing of *Chonetes* in a restricted sense. According to my hasty observations, a septum is commonly present in the ventral valve though it is short and perhaps not very high. In the dorsal valve a septum is well developed in some species, especially in those of Pennsylvanian age; in some Mississippian species, on the other hand, I have been unable to recognize such a structure at all. In the dorsal valve of *Anopliopsis* there are several low ridges or lamellae in the median part but no real median septum.

Like *Chonetes*, again, the inner surface of the ventral valve is covered by numerous spinules arranged in radiating rows. In appearance, at least, specimens differ considerably in this regard. The internal mold (fig. 10) is partly covered by radial ridges (too completely covered in the figure) but the ridges themselves are spinose on top and are replaced by rows of spines laterally. The internal mold (fig. 11) is almost smooth, with distinct spinules only at the sides.

The ventral valve has also cardinal spines which, as in *Chonetes*, project from the angle at the upper margin of the cardinal area. The spines are of course very small and it has not been practicable to show them adequately in the illustrations. They are, in fact, broken off in most specimens though their presence is amply established. They are mostly recognized by the scars or minute perforations which they make along the upper margin of the cardinal area. This evidence, even if there was nothing more tangible would demonstrate a difference from *Anoplia* in which the homologous struc-

tures are few and do not pass completely through the shell substance.

The interior of the dorsal valve is covered as to the lateral parts with spinules, but over the median part these are replaced by continuous lamellae that have a definite and constant arrangement. The lamellae (which theoretically may be regarded as consolidated spines though actually they are thin plates and are not serrated on top) are confined to the median half of the valve, or to the more strongly arched portion, and they are divided into two groups by a relatively wide space down the middle with 6 or 7 lamellae in each group. The median space is unoccupied except as it may contain in the anterior half several lamellae which are short and conspicuously lower than the lamellae on either side. The spinules that replace the lamellae farther out on the auricles are rather large and are radially arranged. The longest and highest lamellae are those adjacent to the median area and the more lateral ones are partly replaced by spinules.

A discussion of the relationship of *Anopliopsis* to *Chonetes* and *Chonetina* is attended by some complexity because the old genus *Chonetes* has been broken up and the new genera created from the fragments have not all been distinguished on the same set of characters and have not been interpreted in the same way or given the same values by all authors.

From *Chonetes* in the broad sense *Anopliopsis* is distinguished by its internal characters especially by the thin high plates developed on the surface of the dorsal valve. In addition to this general difference, it differs from some of the chonetid "genera" in being smooth instead of striated or in being regularly arched without a fold or sinus, or in both ways, characters which have been employed for the disintegration of *Chonetes*.

Anopliopsis shows a striking resemblance to *Chonetina* in the internal characters of the dorsal valve, the characters on which Krotow relied to distinguish *Chonetina* from *Chonetes*, but it shows striking differences in every other character for it is smooth instead of striated, it is regularly arched instead of deflected into a strong fold and sinus, it was developed at the beginning of the Carboniferous period instead of toward its end, and its habitat was in the opposite hemisphere. It is true, of course, that Dunbar and Condra have referred several American species to *Chonetina* but I can see no substantial reason either why those species were distinguished from *Chonetes* s. s. or why they were included under *Chonetina*.

A consideration of *Anopliopsis* in its relation to *Anoplia* was suggested to me by G. A. Cooper, for I had overlooked that genus in canvassing the generic affinities of *A. subcarinata*. In external appearance *Anopliopsis* and *Anoplia* are much alike and each is a monotypic genus. *Anopliopsis* is a true chonetid with cardinal spines like all the rest of the tribe. *Anoplia* as described by Hall and Clarke, on the other hand, has a peculiar structure which may be compared to a single cardinal spine on each side which penetrated the cardinal area but did not reach the surface and of whose presence there is no external evidence. The absence of true cardinal spines in *Anoplia* is confirmed by Dr. Cooper from numerous excellent specimens in the National Museum. He notes points of resemblance between *Anoplia* and *Anopliopsis* in the internal structure (*Anoplia* seems to have similar but less numerous ridges in the brachial valve). He remarks also that the time relations of *Anopliopsis* would suggest a genetic affinity to the Devonian genus *Anoplia* rather than to the Permian *Chonetina*, an opinion in which all must agree (fide his letter of April 10, 1935).

As stated in the beginning, *Anopliopsis* is not proposed as a new genus without some reservations. It is possible that with increased knowledge the

internal differences upon which *Anopliopsis* mainly rests will be bridged so that no satisfactory line of demarcation will be found between *Anopliopsis* and *Chonetes*. This possibility is suggested by a little known species described by Stevens as *Chonetes Michiganensis*. In its external appearance *C. Michiganensis* could be called a normal species of *Chonetes* s. s. It is a large shell, it is not highly arched, and it is marked by irregular, feeble, but quite distinguishable costae. Its internal characters, however, are analogous to those of *A. subcarinata* except that the radial plates are not so high and are obviously compacted of spinules possibly through deposits of callus. Although *Anopliopsis* is endowed with strong individuality by reason of its combination of size, configuration, and sculpture, aside from its internal characters, the fact just mentioned suggests that in its internal characters it may grade into *Chonetes*.

On the other hand, the distinction between *Anopliopsis* and *Chonetina* so far as can be determined, rests mainly upon differences in configuration and sculpture emphasized by differences in time and place of occurrence. Future discoveries may bring to light species constructed like *Anopliopsis* and *Chonetina* which are intermediate in geologic time and are gradational in shape and ornamentation.

ZOOLOGY.—*A new copepod from Japanese oysters transplanted to the Pacific coast of the United States.*[1] CHARLES BRANCH WILSON, State Teachers College, Westfield, Massachusetts. (Communicated by WALDO L. SCHMITT.)

A few years ago some of the large Japanese oysters were transplanted to the Pacific coast of the United States and have thriven well in their new environment. During the past year some of them have been found to be infested with a copepod and specimens have been sent to the present author for identification. These specimens included both sexes and have proved to be a new species, a description and figures of which are here presented.

Mytilicola ostreae, n. sp.

Occurrence.—The copepods are found attached to the inner wall of the stomach of the oyster. There are usually but two or three specimens on one host but as many as twenty have been taken from a single oyster, in which case a considerable portion of the stomach cavity was occupied by them.

Female.—Body elongate, narrow and tapered posteriorly; head separated from the thorax, wider than long, with a small dorsal carapace which is divided longitudinally through its center. The five thoracic segments and the genital segment completely fused, with no indication of separation except the paired dorsal processes. Each thoracic segment bears a pair of these processes near its posterior corners. Each process is triangular in shape and extends diagonally outward and backward, with an acute tip which sometimes curves slightly forward. The first four pairs of processes increase in size posteriorly, the fifth pair are smaller than the fourth. The genital seg-

Received March 2, 1938.

ment is enlarged at its posterior corners, but has no processes. The abdomen is considerably narrower and thinner than the genital segment and tapers a little posteriorly. It is as long as the genital segment and is apparently undivided with smooth lateral margins. The caudal rami are cylindrical, longer than wide and slightly divergent, and show no setae in any of the specimens examined.

The first antennae are 4-segmented, the basal segment large and swollen, the other three segments much smaller, and all four sparsely armed with small spines. The second antennae are 2-segmented, the distal segment in the form of a stout curved claw, divided at its center and each half armed with a spine-like seta. These are the organs which attach the copepod to the stomach wall of its host and keep it from being swept out by the food current of the oyster. The mandible is attached beneath the posterior corner of the upper lip and extends inward and backward. It is cylindrical, unsegmented and so minute that it does not reach inside of the first maxilla, and so can scarcely function at all. The first maxilla is an elliptical mamma, slightly raised above the surface of the head and armed with two short spine-like setae. It is situated behind the corner of the upper lip and fits into a semicircular invagination of the latter. The second maxilla is made up of a stout basal portion attached to the surface of the head and a 2-segmented portion; the end segment is curved and fringed with fine hairs. The maxilliped is lacking in the female. There are four pairs of swimming legs, each leg uniramose and reduced to a simple pointed knob visible only in profile. The ovisacs are elongate conical, tapered to a point distally and three quarters as long as the entire body. The eggs are minute, very irregularly arranged and quite numerous, about 200 in each ovisac. Total length 10 to 12 mm. Greatest width (4th segt.) 1.33 mm. Length of ovisacs 7 mm.

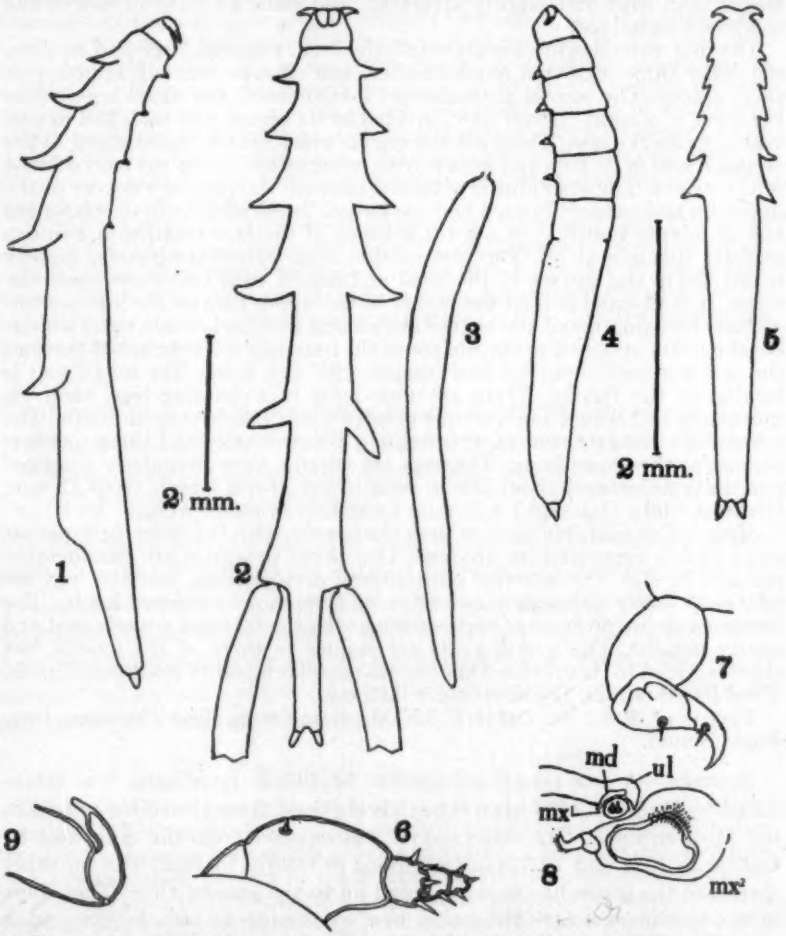
Male.—Considerably smaller than the female, with the thoracic segments more or less separated by grooves. The dorsal processes are considerably reduced in size, the anterior ones almost disappearing, but the legs are relatively larger although they still remain uniramose pointed knobs. The abdomen shows no trace of segmentation; the caudal rami are enlarged and nearly parallel. The mouth parts are similar to those of the female, but there is added to them behind the second maxillae a pair of stout maxillipeds. Total length 4 mm. Greatest width 0.55 mm.

Type.—♂ & ♀, No. 69915 U.S.N.M., from *Ostrea gigas* Thunberg, from Puget Sound.

Remarks.—A new genus and species, *Mytilicola intestinalis*, was established by Steuer in 1903 upon copepods obtained from the edible mussel in the Mediterranean. The same species was reported from the same host by Dollfus in 1914 and 1927 and by Monod & Dollfus in 1932, but no other species of the genus has been proposed up to the present time. That these oyster specimens constitute such a new species can be seen by comparing the swimming legs. In *intestinalis* each leg is biramose and each ramus 2-segmented; in *ostreae* each leg is uniramose and made up of a single segment.

In 1885 Dr. Ramsay Wright described a new genus and species of copepods, *Myicola metisiensis*, found in the common long clam, *Mya arenaria*. In 1914 Dollfus added another new genus and species, *Trochicola enterica*, from certain gastropod mollusks. In 1936 Yamaguti proposed a third new genus and species, *Pseudomyicola ostreae*, from a Japanese oyster, *Ostrea*

denselamellosa. These three are valid genera and with the present genus making a fourth they all agree in having their mouth parts arranged on the general plan found in the Ergasilidae and Bomolochidae. There is an upper



Figs. 1–9.—*Mytilicola ostreae*, n. sp. Fig. 1.—Side view of female. Fig. 2.—Dorsal view of same. Fig. 3.—Ovisac, same magnification as fig. 2. Fig. 4.—Side view of male. Fig. 5.—Dorsal view of same. Fig. 6.—First antenna. Fig. 7.—Second antenna. Fig. 8.—Mouth parts; md, mandible; mx^1, first maxilla; mx^2, second maxilla; ul, upper lip. Fig. 9.—Maxilliped of male.

lip of varying form, beneath whose posterior corners lie a pair of mandibles; behind these are the first maxillae, each consisting of a mamma armed with two or three setae. Then come the second maxillae and in the male the

maxillipeds which are lacking in the female. So complete is this correspondence in all the genera that each mouth part must bear the same name in them all. And when a mouth part is missing those that are present must be named from their position in the general plan and not from their sequence to one another. For example if the mandible is lacking the mamma behind the posterior corners of the upper lip can not be called the mandible although it is the first visible mouth part. Its position tells that it is still the first maxilla.

Since the mandible was lacking in the type species of both *Mytilicola* and *Trochicola* this mamma with its setae was designated as the mandible. This name was changed by Dollfus in later publications for the genus *Trochicola*, and by Monod & Dollfus in 1932 for the genus *Mytilicola*, and this mouth part was correctly named the first maxilla.

It is misleading to designate these copepods as parasites without qualification since that word implies that they feed upon the fluids or the tissues of their host. They should be designated as commensals or at the worst as semiparasites. As can be readily seen from the preceding description the mouth parts are not suited for sucking blood or biting the body tissues of the host. In all probability these copepods subsist by appropriating a portion of the food that would otherwise serve to nourish the oyster. They are not, therefore, definitely harmful, yet their mere presence may not be considered altogether desirable. The fact that they breed prolifically in the ocean instead of in a confined body of water makes it practically impossible to eradicate them. But there is a possibility that they might be banished during the marketing of the oysters.

The digestive fluids connected with the oyster's stomach evidently contain nothing that is injurious to the copepods. Not only do these commensal copepods live and breed there but pelagic species also are often found swimming freely within the stomach. In the present instance a specimen of *Paracalanus* was found in one of the oyster stomachs along with the *Mytilicola* specimens.

Since these copepods are attached to the inner wall of the oyster's stomach even if something could be found that would kill them without injury to the oyster they would remain still attached after death and could be removed only by mechanical means.

Fortunately as stated above there is nothing in the presence of these copepods that is deleterious either to the oysters themselves or to the consumption of them. Recognition of this fact ought to remove any predjudice against their use for food just as it has done in the case of our fish. There is scarcely a single species of food fish that is not more or less infested with parasitic copepods, and these copepods are the genuine parasites feeding on the blood and fluids of the fish. The swordfish is one of those most completely parasitized, both externally and internally; it is safe to say that not a single one of them found in our markets was free from such infection at the time of its

capture. And yet they still remain among the fish commanding the highest market prices and are savory to hundreds of thousands of palates including that of the author. Let the oysters join the fish and exclude all remembrance of the copepods.

ENTOMOLOGY.—*A key to the genera of chiggers (mite larvae of the subfamily Trombiculinae) with descriptions of new genera and species.*[1] H. E. EWING, Bureau of Entomology and Plant Quarantine.

When the present writer began the study of chiggers some years ago only a few species were sufficiently well known to have received names. In the United States only a single species had been named. Today there are known from the New World no less than sixty-five named species and almost as many from the Old World. Because so many species are in this economic group, and particularly because one of them is known to be a transmitter of Kedani fever, a serious disease of man, their study is assuming much importance.

HOST RELATIONSHIPS

The only genera that are here included in the subfamily Trombiculinae are those whose species are believed to have vertebrates as their natural hosts. Although several species have been reported as having both invertebrate and vertebrate hosts, such reports probably are in error. This certainly must be true of a few species with which the writer is familiar. For example, *Trombidium striaticeps* Oudemans which has been reported from both vertebrate and invertebrate hosts, occurs commonly about Washington, D. C., as a parasite of various insects, such as *Musca domestica* and *Stomoxys calcitrans;* yet from the many hundreds of vertebrate hosts from this vicinity examined for chiggers by the writer no specimens of *T. striaticeps* have been taken. In fact, among the many thousands of larvae of Trombiculinae from both North and South America examined by the writer, those of no species have been found to parasitize both invertebrates and vertebrates.

Records of chiggers of a single species from both vertebrate and invertebrate hosts have resulted in most cases, it is believed, either from misidentifications or from finding unattached chiggers wandering over a presumed host, just as they would wander over any other object in their environment. Further observations will eventually enable us to decide whether such species have either vertebrates or

[1] Received March 2, 1938.

invertebrates as hosts, and thus allocate them to their proper subfamily.

POSSIBLE VARIATIONS IN THE NUMBER OF PRONGS ON THE PALPAL CLAW

Several workers have remarked, in describing larvae of a chigger species, that the number of prongs on the palpal claw varies. It is

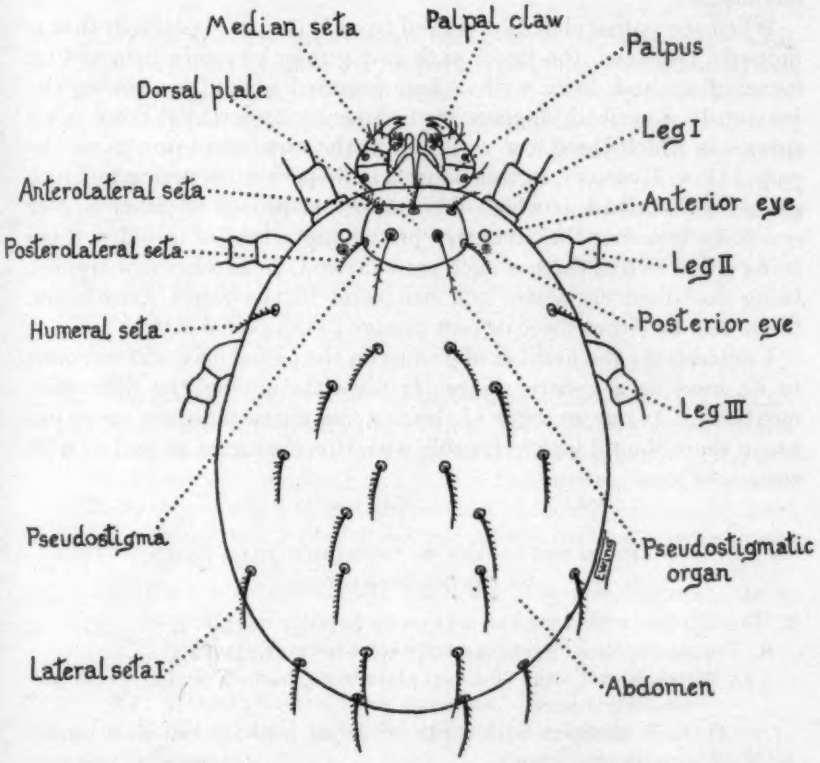


Fig. 1.—Dorsal view of the common North American chigger, *Eutrombicula alfreddugèsi* (Oudemans), with parts labeled. Greatly enlarged.

probable that most of this supposed variation is due to the fact that one prong is so small or so closely appressed to the claw proper that it has been overlooked.

The success one has in counting these prongs depends largely on two factors—the proper clearing of the specimen, and the viewing

of the palpal claw from below. In poorly cleared specimens, particularly those mounted in balsam, the prongs of many species can not properly be seen. Specimens that have been partly crushed by having an insufficiency of mounting medium on the microscope slide—and there are very many such specimens in most collections—will have the palpi spread out laterally so that they occupy an unnatural, horizontal position. In such a position the palpal claw can not be seen to advantage.

When the palpal claw is observed from below in a specimen that is properly mounted, the tip of each prong may be easily detected by focusing up and down with a high-powered objective. Among the previously described chiggers from America apparently there is no species in which there is a variation in the number of prongs on the palpal claw. However, in this paper a new species, belonging to a new genus, is described in which the number of prongs is either five or seven. In this case the accessory prongs are arranged in pairs, there being either two or three of such pairs present. In another new species, being described elsewhere and belonging to the genus *Trombicula*, there may be either three or four prongs to the palpal claw.

Undoubtedly the number of prongs on the palpal claw will continue to be used as a generic character notwithstanding the difficulties mentioned. As our methods of clearing and mounting these mites improve there should be less trouble with this character as well as with certain others.

A KEY TO THE GENERA OF THROMBICULINAE, BASED ON LARVAL CHARACTERS

A. Dorsal plate with a median seta on its anterior margin.
  B. Pseudostigmatic organs strongly clavate or capitate.
    C. Anterolateral setae of dorsal plate large, barbed, similar to the posterolateral setae.
      D. Each chelicera with a row of dorsal teeth; palpal claw usually with two prongs.....*Schöngastia* Oudemans
      DD. Each chelicera with not more than one dorsal tooth.
        E. Palpal claw with two or three prongs.....*Neoschöngastia* Ewing
        EE. Palpal claw with five or seven prongs, the accessory prongs being in two or three pairs; dorsal tooth of chelicera vestigial or absent.....*Euschöngastia*, new genus
    CC. Anterolateral setae of dorsal plate minute, simple. Parasitic on bats.....*Doloisia* Oudemans

BB. Pseudostigmatic organs setiform or flagelliform, frequently with barbs.
C. Each chelicera with a row of dorsal teeth; ventral tooth sometimes absent.
D. More than three subequal dorsal teeth on each chelicera; dorsal plate well developed; median seta pectinate. *Odontacarus* Ewing
DD. Three unequal dorsal teeth on each chelicera; dorsal plate vestigial; median seta simple. Living under surface of skin of amphibians..... *Endotrombicula* Ewing
CC. Each chelicera with a single dorsal tooth; ventral tooth present.
D. Palpal claw typically divided into three prongs; dorsal abdominal setae usually more than 30..... *Trombicula* Berlese
DD. Palpal claw divided into two prongs; dorsal abdominal setae usually less than 30..... *Eutrombicula*, new genus
AA. Dorsal plate without median seta.
B. Dorsal plate with a pair of submedian setae on anterior margin.
C. Dorsal plate with an anterior median process but without crista... ..... *Leeuwenhoekia* Oudemans
CC. Dorsal plate without anterior median process but frequently with crista; each chelicera obliquely flattened at distal end, forming a "spearhead" with teeth on its lateral margin..... ..... *Hannemania* Oudemans
BB. Dorsal plate without a pair of submedian setae on anterior margin.
C. Each tarsus armed with two unequal claws; pseudostigmatic organs represented by a pair of simple setae; all setae, both on body and appendages, simple..... *Hemitrombicula*, new genus
CC. Each tarsus armed with three claws, the middle one usually more slender and longer than the others; pseudostigmatic organs clavate or capitate.
D. All setae on dorsal plate (exclusive of pseudostigmatic organs) marginal.
E. Dorsal plate with four or more pairs of lateral setae..... ..... *Gahrliepia* Oudemans
EE. Dorsal plate with less than four pairs of lateral setae.
F. Dorsal plate with three pairs of lateral setae; eyes present.. ..... *Schöngastiella* Hirst
FF. Dorsal plate with two pairs of lateral setae; eyes absent.. ..... *Walchia* Ewing
DD. Some of setae on dorsal plate not marginal; eyes usually present ..... *Gateria*, new genus

GENERIC HOMONYM AND SYNONYMS

The name *Typhlothrombium* Oudemans (1910, Nov. 1), proposed for *T. nanus* Oudemans, was found to be preoccupied by *Typhlo-*

thrombium Berlese established earlier in the same year. In its place Oudemans proposed in 1912 the name *Gahrliepia.*

The generic name *Otonissus* Kolenati (1856)[2] comes into consideration in the subfamily Trombiculinae. Oudemans[3] has pointed out that one of the species originally included in *Otonissus, O. aurantiacus* Kolenati, is a larval form of Trombidiidae that would be included in Berlese's *Trombicula* as defined by Berlese. The eminent Dutch authority even lists *Trombicula* as a synonym of *Otonissus,* which he spells *Otonyssus,* following a later emendation by Kolenati. In view of the fact that *Trombicula* has become greatly restricted in recent years there can be no justification for this suggested synonymy.

The name *Leptotrombidium* Nagayo, Miyagawa, Mitamura and Imamura, proposed in 1917[4] for the Kedani mite, has been considered by subsequent workers as a synonym of *Trombicula.* Objections might well be raised against such a practice as an investigation of the use of the name *Trombicula* shows.

The generic name *Trombicula* Berlese appears to have been first applied to a larval form of the subfamily Trombiculinae in 1918 by Kitashima and Miyajima.[5] In this paper they claimed that the adult of the Kedani mite, then known as *Leptus akamushi* (Brumpt), was the same as *Trombicula coarctata* Berlese. Although subsequent investigation has shown that the Kedani mite is different from *T. coarctata* Berlese, it also has shown that this Japanese mite does belong to the genus *Trombicula,* as defined in a broad sense by Berlese.

It is very unfortunate, however, that the type species of *Trombicula, T. minor* Berlese, has every appearance of being established on a nymphal form. Until the larva or adult of this type species has been obtained by breeding, the status not only of the genus *Trombicula* but of all the genera of Trombiculinae will be somewhat in doubt.

Neotrombicula Hirst (1925)[6] was established as a subgenus for *Leptus autumnalis* Shaw, the common chigger of Europe. It should be regarded as a synonym of *Leptotrombidium,* since the palpal claw of the larva of the type species is trifurcate, and the other larval characters are those of the *akamushi* group of chiggers (*Trombicula, sensu stricto*).

[2] KOLENATI, F. A. *Die Parasiten der Chiroptern,* p. 17. Brünn, Rudolf Rohrers Erben.

[3] OUDEMANS, A. C. *Kritisch Historisch Overzicht der Acarologie,* Part III, Vol. D, p. 1362. 1937.

[4] NAGAYO, M., MIYAGAWA, Y., MITAMURA, T., and IMAMURA, A. Jour. Exp. Med. **25**: 255.

[5] KITASHIMA, T., and MIYAJIMA, M. Kitasato Arch. Exp. Med. **2**: Nos. 2–3. 1918.

[6] HIRST, S. Nature **116**: 609. 1925.

DESCRIPTION OF NEW GENERA AND SPECIES

Four new genera and two new species, both type species, are described in the following pages. Types are deposited in the United States National Museum.

Euschöngastia, new genus

Chelicerae each with a vestigial dorsal tooth or none. Palpal claw with five or seven prongs. Eyes present. Dorsal plate with posterolateral corners, without anterior median process, without crista. Median seta of dorsal plate present, barbed; anterolateral setae barbed; submedian setae absent; total number of setae on dorsal plate (exclusive of pseudostigmatic organs) five. Pseudostigmatic organs clavate or capitate. Dorsal abdominal setae numerous, barbed, arranged in very irregular, transverse rows. Legs and tarsal claws typical of the subfamily Trombiculinae.

Type species.—Euschöngastia americana, n. sp.

Only the type species is included in *Euschöngastia.* The genus is near *Neoschöngastia* Ewing, from which it differs in having the palpal claw either five-, or seven-pronged instead of two-, or three-pronged.

Euschöngastia americana, n. sp.

Palpus short, broad near base and rapidly narrowing to apex; segment II angulate laterally; first palpal seta semiplumose; second well supplied with rather slender barbs; third barbed. A single eye present on each side of cephalothorax near lateral margin. Dorsal plate over twice as broad as long; anterior margin slightly incurved; posterior margin very broadly rounded. A crescent-shaped ridge present in front of each pseudostigma. Pseudostigmatic organs strongly clavate, barbed, extending backward beyond posterior margin of dorsal plate. Dorsal abdominal setae about 40; humerals not situated in first row, which includes 12 setae; second row irregular, containing 8 setae. Other dorsal setae not arranged in rows. Legs moderate in length; tarsus I with short dorsal spine situated about twice its length from base of segment and tactile seta situated on a broad tubercle.

Length of engorged specimen, 0.58 mm; width, 0.37 mm.

Type host.—Chipmunk, *Eutamias* sp.

Type locality.—Boise, Idaho.

Type slide.—U.S.N.M. No. 1277.

Remarks.—Described from eight engorged specimens taken from type host at type locality, September 20, 1930, by S. B. Locke, and three partly engorged specimens taken from a "mouse" at San Simeon, Calif., June 7, 1931, by R. L. Boke.

Eutrombicula, new genus

Chelicerae each with a single dorsal tooth. Palpal claw bifurcate. Eyes present. Dorsal plate with posterolateral corners, without anterior median process, without crista. Median seta of dorsal plate present, barbed; anterolateral setae with barbs; submedian setae absent; total number of setae on dorsal plate (exclusive of pseudostigmatic organs) five, all marginal. Pseudostigmatic organs setiform or flagelliform, with or without barbs. Dorsal abdominal setae usually less than thirty, barbed, arranged in more or less

irregular transverse rows. Legs and tarsal claws typical for the subfamily Trombiculinae.

Type species.—*Microthrombidium alfreddugèsi* Oudemans.

This new genus includes the species of the *alfreddugèsi* group of the genus *Trombicula*. The following North American species are transferred to it: *Microthrombidium alfreddugèsi* Oudemans, *Trombicula hominis* Ewing, *Trombicula flui* van Theil, *Trombicula butantanensis* Fl. da Fonseca, *Trombicula tropica* Ewing, *Trombicula insularis* Ewing, *Trombicula brasiliensis* Ewing, *Microthrombidium bruyanti* Oudemans, *Trombicula harperi* Ewing, *Trombicula ophidica* Fl. da Fonseca, *Microthrombidium göldii* Oudemans, *Microthrombidium helleri* Oudemans, *Microthrombidium tinami* Oudemans, *Trombicula dunni* Ewing, *Trombicula yorkei* Sambon, *Trombicula myotis* Ewing, *Trombicula panamensis* Ewing, *Trombicula gurneyi* Ewing, and *Trombicula cavicola* Ewing.

Doubtfully included in this genus are the South American species *Trombicula ewingi* Fl. da Fonseca and *Trombicula travassosi* Fl. da Fonseca. In both of these species the anterolateral setae of the dorsal plate are short, very stout, and peglike. The present writer has not yet seen a specimen of either species, but it appears to him that they should be put into a new genus, or at least into a new subgenus.

Some Old World species should go into *Eutrombicula*, but mounted specimens of such species are not available for study.

Hemitrombicula, new genus

Chelicerae each with a single dorsal tooth. Palpal claw bifurcate. Eyes present. Dorsal plate without posterior corners, anterior median process, or crista. Median seta of dorsal plate absent; anterolateral setae simple, similar to other setae on dorsal plate; submedian setae absent; total number of setae on dorsal plate (exclusive of pseudostigmatic organs) six, all of which are marginal. Pseudostigmatic organs simple, similar to other setae borne by dorsal plate. Dorsal abdominal setae simple, not numerous, arranged in transverse rows. Tarsi each with two unequal slender claws.

Type species.—*Hemitrombicula simplex*, new species.

Only the type species is included. This genus differs from all others of its subfamily in having only two claws to each tarsus instead of three, and in having the pseudostigmatic organs represented by a pair of simple setae.

Hemitrombicula simplex, n. sp.

Palpus slender, extending slightly beyond tips of chelicerae; second segment broadly rounded laterally; third segment long, about one and one-half times as long as second; thumb short, cone-shaped. All palpal setae simple, slightly curved. Anterior eye much larger than posterior and situated almost its diameter from latter; both eyes on sclerotized plate. Dorsal plate about as broad as long; anterior margin almost straight; posterior margin broadly rounded. Pseudostigmata absent. Pseudostigmatic organs represented by a pair of simple setae situated at about middle of dorsal plate. Dorsal abdominal setae simple, curved, each situated on a minute chitinous (? sclero-

tized) disc; total number about 20; humerals absent. Legs of moderate length; tarsus I without dorsal spine or specialized tactile seta.

Length of engorged specimen, 0.69 mm; width, 0.45 mm.

Type host.—Pilot black snake, *Elaphe obsoleta obsoleta* (Say).

Type locality.—Camp Bryan, Cass County, Mich.

Type slide.—U.S.N.M. No. 1278.

Remarks.—Described from two engorged specimens taken from type host at type locality during July, 1931, by P. C. Trexler. Professor Trexler wrote as follows in regard to these chiggers: "The red acarina were taken from the mouth of the snake, where they were attached so firmly that they were difficult to remove without crushing. There were ten specimens attached between the rows of teeth on the upper jaw only."

The snake from which these chiggers were taken was six feet long, and was infested also with our common chigger, *Eutrombicula alfreddugèsi* (Oudemans). The larvae of *E. alfreddugèsi* were found exclusively between the scales on the neck of the host. Of the ten specimens of *H. simplex* observed by the collector only two were seen by the present writer.

Gateria, new genus

Chelicerae each with a single dorsal tooth. Palpal claw trifurcate. Eyes reduced, vestigial or absent. Dorsal plate very large, without posterolateral corners, without anterior median process, without crista. Median seta of dorsal plate absent, anterolateral setae with barbs, similar to other setae on dorsal plate; submedian setae absent; total number of setae on dorsal plate (exclusive of pseudostigmatic organs) twelve or more, some of which are not marginal. Pseudostigmatic organs clavate. Dorsal abdominal setae with barbs and arranged in somewhat irregular transverse rows. Middle and hind legs with only six segments each. Tarsi each with three claws as in related genera.

Type species.—*Gahrliepia fletcheri* Gater.

Other species included are *Gahrliepia ciliata* Gater and *G. rutila* Gater. When Gater (1932)[7] described the type species of this genus he not only placed it in the genus *Gahrliepia*, a genus based on a species with only eight setae on the dorsal plate, but at the same time placed Hirst's genus *Schöngastiella* in the synonymy of *Gahrliepia*. His reasons for so doing he states in part as follows, "the fact that the number of scutal setae, posterior to the first two pairs, varies in different specimens of *G. fletcheri* from the same cluster, leads me to believe that the number of scutal setae is not a sound criterion for the separation of genera in this group." The present writer agrees with Gater in part only. It should be noted that individual variation in the number of setae has never been found in any species in which the total number of such setae is less than ten. In the new genus here proposed the important point about the setae on the dorsal plate is not their number, but the fact that some of them are not marginal.

[7] GATER, B. A. R. Parasitology 24: 161.

Obituary

MAURICE CROWTHER HALL, parasitologist, Chief, Division of Zoology, National Institute of Health, U. S. Public Health Service, died on May 1, 1938, at the Walter Reed General Hospital following an operation for gastric ulcers. He was buried May 4, in Arlington National Cemetery, with full military honors.

Dr. Hall was born July 15, 1881, at Golden, Colorado. He was graduated with the B.S. degree from Colorado College in 1905; he received the M.S. degree from the University of Nebraska in 1906, and the Ph.D. and D.V.M. degrees from the George Washington University in 1915 and 1916, respectively. After teaching in high school for one year, he came to Washington, D. C., in 1907 to join the staff of the Zoological Division of the Bureau of Animal Industry, U. S. Department of Agriculture. In 1916 he resigned from the Bureau of Animal Industry to become research parasitologist for Parke, Davis and Company. He served in the army during the world war as a lieutenant in the newly organized veterinary corps. In 1919 he returned to the Bureau of Animal Industry as assistant chief of the Zoological Division, becoming chief of that division in 1925, following the death of B. H. Ransom. In 1936 he resigned his position in the Bureau of Animal Industry to become Chief of the Division of Zoology of the National Institute of Health.

Dr. Hall's researches in the field of veterinary and medical parasitology won for him recognition as one of the world's foremost parasitologists. His most important work was in the field of anthelmintic medication. His discovery in 1921 of the value of carbon tetrachloride and in 1925 of the value of tetrachlorethylene, as effective treatments for the removal of hookworms from dogs led to the adoption of these drugs as standard treatments for the removal of hookworms from man, resulting in the saving of thousands of lives and restoring many more thousands to physical and economic usefulness. He was also responsible for the standardization of many of the anthelmintics in common use in veterinary practice. His publications in the fields of parasitology and therapeutics total more than 550 titles. In addition to papers in these fields, he published a number of papers on the philosophical and social aspects of parasitism, government, and other topics. In recognition of his contributions to science the honorary Sc.D. degree was conferred upon him in 1925 by his alma mater.

Dr. Hall was a member of the American Association for the Advancement of Science, American Society of Parasitologists (pres. 1932), American Society of Zoologists, Entomological Society of America, American Association of Economic Entomologists, American Veterinary Medical Association (pres. 1930), U. S. Livestock Sanitary Association, American Society of Tropical Medicine, American Academy of Tropical Medicine, Helminthological Society of Washington (pres. 1922), Entomological Society of Washington, Washington Academy of Sciences (v. pres. 1925), Royal Academy of Agriculture of Torino, Phi Beta Kappa and Sigma Xi.